WEIGHT CHARACTERISTICS OF BIRDS KILLED IN NOCTURNAL MIGRATION

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From the toll of nocturnal migrants at ceilometer beams, television towers, and other structures, ornithologists have learned much about migration and about population characteristics of a variety of species. Exemplary studies are those by Tordoff and Mengel (1956) and Brewer and Ellis (1958).

These and a host of other papers on the subject have pointed out the possibilities for research. Specimens from tower kills are a valuable source of information on birds and continue to deserve study.

The present study of organ weights of nocturnal migrants was initiated in the fall of 1958 using specimens collected at the same site described by Brewer and Ellis (1958).

METHODS

In connection with a study program on nocturnal migration in central Illinois, we made daily morning visits in season to the WCIA television tower located about 10 miles west of Champaign, Illinois, to collect fresh specimens in the event of a kill. (For complete information on the tower, see Brewer and Ellis, 1958.) We picked up a few scattered specimens at various times between March 1958 and November 1960, but virtually all of the specimens reported in this paper represent three kills on the nights of 16–17 September 1958; 28–29 September 1959; and 18–19 September 1960.

We collected specimens in the morning following the kill, and recorded gross weights immediately after on a Fisher triple beam, 500-gram capacity, balance. The birds were then sealed in plastic bags and placed in a freezer. Small numbers of specimens (to 35) were thawed at one time and dissected as quickly as possible. Because of the time-consuming nature of the work, as much as two months elapsed before all specimens in a sample were dissected.

In dissecting the specimens, the skin was first removed and the condition of fat deposition noted. Fat condition was subjectively evaluated on a scale from 0 (no fat) to 5 (extremely fat), and more objectively evaluated by measuring with a millimeter rule the cut depth of fat deposit on the sides of the abdomen.

The mass of pectoral muscle was next removed from the sternum and the weight for pectoral mass included all of the muscle lying on the sternum to one side of the keel from the points of origin to insertion. Initially, the mass on both sides of the keel were weighed separately, but no consistent difference was apparent in a sample of 20 birds representing four species. Thereafter,

Table 1

Weight Characteristics of Thrushes Killed in Nocturnal Migration in Fall, 1958, 1959, and 1960 at Champaign, Illinois[1]

	Sample size	Gross		Fat condition		Pectoral mass		Brain		Heart		Lung		Liver	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
SWAINSON'S THRUSH															
Adult Male															
1958	23	32.8	0.94	2.6	0.23	2.82	0.04			0.47	0.01	0.23	0.02	1.27	0.07
1959	20	32.0	0.47	2.0	0.18	2.87	0.05			0.45	0.03	0.24	0.03	1.23	0.06
1960	12	30.3	0.46	1.4	0.30	2.57	0.03	0.79	0.01	0.49	0.02	0.23	0.02	1.32	0.07
Adult Female															
1958	11	31.7	1.12	2.4	0.42	2.60	0.06			0.47	0.02	0.22	0.01	1.16	0.04
1959	17	30.8	0.68	1.8	0.29	2.61	0.04			0.44	0.01	0.23	0.01	1.19	0.04
1960	7	28.6		1.1		2.29		0.85	0.05	0.46		0.23		1.23	
GRAY-CHEEKED THRUSH															
Adult Male															
1958	12	34.8	0.70	2.8	0.27	2.93	0.06			0.53	0.02	0.24	0.01	1.42	0.09
1959	3	33.5		2.3		3.16				0.52		0.23		1.32	
1960	10	31.3	0.33	1.7	0.33	2.73	0.08	0.80	0.02	0.52	0.03	0.24	0.01	1.26	0.08

[1] Mean and standard error shown in grams.

only the right breast muscle was weighed unless it was macerated or aberrant.

The sternum was lifted next and the heart removed by cutting blood vessels as close to the structure as possible. No effort was made to remove blood from the hearts' chambers before weighing and our heart weights are high by comparison with those given by Hartman (1955).

The least hemorrhagic of the two lungs was removed and weighed without regard to position. As far as we could determine, there was no consistent difference in weight between right and left lung.

Liver, spleen, and brain were weighed entire.

Organ weights were taken on an analytical balance with a sensitivity of 1 milligram and a capacity of 50 grams. Organs were weighed only if they appeared to be intact.

Statistical evaluations were made on all samples of eight or more items, but to keep Table 2 within reasonable bounds, only the means are presented. Data on variability in the larger samples are presented in Table 1.

Weight differences were considered significant at the 0.10 level.

THE KILLS

Cochran and Graber (1958) and Graber and Cochran (1960) discussed the meteorological conditions which accompany fall kills at the WCIA tower.

TABLE 2

WEIGHT CHARACTERISTICS OF BIRDS KILLED IN NOCTURNAL MIGRATION

Species, sex, and age	Sample size	Gross	Fat class	Pectoral mass Mean	Pectoral mass %	Brain Mean	Brain %	Heart Mean	Heart %	Lung Mean	Lung %	Liver Mean	Liver %
Short-billed Marsh Wren (*Cistothorus platensis*)													
♀ Imm.	5	8.3	2.4	0.448	5.4			0.140	1.7	0.057	0.7	0.325	3.9
Catbird (*Dumetella carolinensis*)													
♂ Ad.	4	40.9	3.7	2.958	7.2			0.572	1.4	0.301	0.7	1.567	3.8
Imm.	3	39.3	3.3	2.748	7.0			0.497	1.3	0.256	0.6	1.748	4.4
♀ Ad.	13	38.3	2.5	2.701	7.0	1.037	2.7	0.524	1.4	0.249	0.6	1.521	4.0
Imm.	9	38.2	2.5	2.644	6.9	1.209	3.2	0.523	1.4	0.246	0.6	1.688	4.4
Wood Thrush (*Hylocichla mustelina*)													
♂ Ad.	1	53.4	2.0	5.146	9.6			0.834	1.6	0.415	0.8	2.040	3.8
Imm.	2	53.8	3.0	4.586	8.5			0.711	1.3	0.448	0.8	2.659	4.9
♀ Ad.													
Imm.	2	51.1	3.0	4.166	8.1			0.615	1.2	0.370	0.7	2.358	4.6
Swainson's Thrush (*Hylocichla ustulata*)													
♂ Ad.	56	32.0	2.3	2.786	8.7	0.786	2.5	0.466	1.5	0.234	0.7	1.265	3.9
Imm.	18	32.8	2.4	2.803	8.5	0.964	2.9	0.486	1.5	0.257	0.8	1.458	4.4
♀ Ad.	37	30.7	1.9	2.552	8.3	0.851	2.8	0.457	1.5	0.226	0.7	1.183	3.8
Imm.	14	31.2	2.0	2.501	8.0	0.964	3.1	0.437	1.4	0.222	0.7	1.218	3.9
Gray-cheeked Thrush (*Hylocichla minima*)													
♂ Ad.	25	33.3	2.3	2.880	8.6	0.799	2.4	0.525	1.6	0.249	0.7	1.346	4.0
Imm.	8	33.6	2.5	2.793	8.3	0.942	2.8	0.507	1.5	0.240	0.7	1.453	4.3
♀ Ad.	19	31.1	1.7	2.675	8.6	0.808	2.6	0.507	1.6	0.242	0.8	1.392	4.5
Imm.	5	31.2	1.8	2.614	8.4	0.911	2.9	0.456	1.5	0.256	0.8	1.327	4.2
Veery (*Hylocichla fuscescens*)													
♂ Ad.	2	33.5	3.5	3.148	9.4			0.555	1.7	0.257	0.8	1.630	4.9
♀ Ad.	1	30.5	1.0	2.789	9.2			0.546	1.8	0.192	0.6	1.151	3.8
Red-eyed Vireo (*Vireo olivaceus*)													
♂ Ad.	7	19.2	2.3	1.611	8.4	0.595	3.1	0.398	2.1	0.208	1.1	0.733	3.8
Imm.	8	19.6	2.2	1.488	7.6	0.685	3.5	0.342	1.7	0.178	0.9	0.871	4.4
♀ Ad.	6	19.1	2.8	1.532	8.0	0.579	3.0	0.332	1.7	0.141	0.7	0.654	3.4
Imm.	9	18.8	2.6	1.468	7.8	0.683	3.6	0.312	1.7	0.140	0.7	0.748	4.0
Philadelphia Vireo (*Vireo philadelphicus*)													
♂ Ad.	2	13.2	2.0	1.060	8.0	0.494	3.7	0.246	1.9	0.108	0.8	0.495	3.7
Imm.	3	12.8	2.0	0.980	7.7	0.552	4.3	0.273	2.1	0.109	0.8	0.574	4.5
♀ Ad.	2	12.4	1.5	0.957	7.7	0.473	3.8	0.238	1.9	0.078	0.6	0.467	3.8
Imm.	2	15.6	4.0	1.131	7.2			0.224	1.4	0.081	0.5	0.535	3.4
Black-and-white Warbler (*Mniotilta varia*)													
♂ Ad.	2	10.7	1.5	0.737	6.9	0.388	3.6	0.153	1.4	0.056	0.5	0.373	3.5
Imm.	2	12.2	1.5	0.801	6.6	0.548	4.5	0.168	1.4	0.074	0.6	0.465	3.8
♀ Ad.	4	10.2	1.5	0.839	8.2	0.348	3.4	0.164	1.6	0.078	0.8	0.391	3.8
Tennessee Warbler (*Vermivora peregrina*)													
♂ Ad.	6	10.3	2.2	0.813	7.9	0.388	3.8	0.204	2.0	0.088	0.8	0.454	4.4
Imm.	2	11.4	3.0	0.801	7.0	0.451	4.0	0.171	1.5	0.079	0.7	0.521	4.6
♀ Ad.	7	9.6	2.2	0.801	8.3			0.173	1.8	0.082	0.8	0.407	4.2

	Imm.	7	10.1	3.0	0.768	7.6	0.455	4.5	0.164	1.6	0.072	0.7	0.470	4.7
Magnolia Warbler (*Dendroica magnolia*)														
♂	Ad.	8	9.0	2.2	0.681	7.6	0.381	4.2	0.148	1.6	0.067	0.7	0.362	4.0
	Imm.	1	8.3	1.0	0.633	7.6	0.421	5.1	0.163	2.0	0.063	0.8	0.431	5.2
♀	Ad.	10	8.7	2.2	0.661	7.6	0.379	4.4	0.135	1.5	0.064	0.7	0.351	4.0
	Imm.	2	8.4	2.0	0.564	6.7			0.115	1.4	0.045	0.5	0.321	3.8
Blackburnian Warbler (*Dendroica fusca*)														
♂	Imm.	1	9.9	1.0	0.695	7.0	0.461	4.7	0.205	2.1	0.092	0.9	0.510	5.1
♀	Ad.	1	9.2	1.0	0.778	8.5			0.150	1.6	0.071	0.8	0.508	5.5
	Imm.	1	7.6		0.500	6.6	0.418	5.5	0.179	2.3	0.071	0.9	0.353	4.6
Chestnut-sided Warbler (*Dendroica pensylvanica*)														
♂	Ad.	4	10.2	1.5	0.842	8.2			0.162	1.6	0.074	0.7	0.424	4.2
	Imm.	1	11.5	2.0	0.713	6.2	0.525	4.6	0.201	1.7	0.056	0.5	0.435	3.8
♀	Ad.	9	9.8	2.0	0.719	7.7	0.390	4.0	0.171	1.7	0.072	0.7	0.411	4.2
	Imm.	1	8.8	3.0	0.699	7.9			0.132	1.5	0.058	0.7	0.471	5.3
Bay-breasted Warbler (*Dendroica castanea*)														
♂	Ad.	3	13.3	2.0	1.134	8.5			0.204	1.5	0.093	0.7	0.501	3.8
	Imm.	1	12.1	1.0	0.993	8.2	0.503	4.2	0.217	1.8	0.078	0.6	0.505	4.2
♀	Ad.	4	11.9	1.5	0.956	8.0	0.405	3.4	0.188	1.6	0.094	0.8	0.491	4.1
	Imm.	1	11.9	1.0	0.934	7.8			0.167	1.4	0.065	0.5	0.507	4.3
Palm Warbler (*Dendroica palmarum*)														
♀	Imm.	3	10.2	4.5	0.914	9.0			0.181	1.8	0.069	0.7	0.480	4.7
Ovenbird (*Seiurus aurocapillus*)														
♂	Ad.	15	20.4	2.5	1.847	9.1	0.640	3.1	0.319	1.6	0.138	0.7	0.648	3.2
	Imm.	5	20.6	2.6	1.711	8.3	0.666	3.2	0.312	1.5	0.141	0.7	0.714	3.5
♀	Ad.	27	19.7	2.0	1.733	8.8	0.662	3.4	0.307	1.6	0.140	0.7	0.689	3.5
	Imm.	11	22.5	3.4	1.881	8.4	0.780	3.5	0.287	1.3	0.134	0.6	0.806	3.6
Yellowthroat (*Geothlypis trichas*)														
♂	Ad.	4	11.9	3.2	0.752	6.3	0.482	4.0	0.191	1.6	0.077	0.6	0.433	3.6
	Imm.													
♀	Ad.	8	11.7	3.2	0.631	5.4	0.465	4.0	0.163	1.4	0.072	0.6	0.443	3.8
	Imm.	3	11.9	3.3	0.668	5.6	0.571	4.8	0.164	1.4	0.067	0.6	0.479	4.0
American Redstart (*Setophaga ruticilla*)														
♂	Ad.	9	8.6	2.0	0.678	7.9	0.313	3.6	0.145	1.7	0.061	0.7	0.355	4.1
	Imm.													
♀	Ad.	8	8.1	2.0	0.578	7.1	0.307	3.8	0.144	1.8	0.065	0.8	0.361	4.5
	Imm.	2	9.1	2.5	0.637	7.0	0.400	4.4	0.141	1.5	0.053	0.6	0.413	4.5
Bobolink (*Dolichonyx oryzivorus*)*														
♂	Ad.	10	50.7	5.0	3.391	6.7	1.064	2.1	0.578	1.1	0.290	0.6	1.224	2.4
♀	Ad.	7	39.9	5.0	2.771	6.9			0.440	1.1	0.201	0.5	0.969	2.4
Scarlet Tanager (*Piranga olivacea*)														
♂	Ad.	3	32.0	2.0	2.716	8.5			0.510	1.6	0.228	0.7	0.794	2.5
♀	Ad.	1	32.8	4.0	2.759	8.4			0.435	1.3	0.235	0.7	1.319	4.0
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)														
♂	Ad.	2	46.6	1.5	4.122	8.8			0.666	1.4	0.355	0.8	1.464	3.1
	Imm.	2	50.0	2.5	4.370	8.7	1.449	2.9	0.807	1.6	0.372	0.7	1.734	3.5
♀	Ad.	8	48.1	2.0	4.023	8.4			0.687	1.4	0.376	0.8	1.573	3.3

* Because of extreme fat condition, relative organ weights (per cent of gross) are distorted badly in the Bobolink.

The conditions, usually initiated by a slow-moving cold front, are complete overcast and reduced visibility usually with fog or precipitation.

With detailed migration data and weather records available from the University of Illinois airport and Chanute Air Base, we were able to determine precisely when heavy mortality probably occurred during the nights of the kills.

Aural records (Graber and Cochran, 1960) showed that migrants were moving in the vicinity of Champaign throughout the night of 16–17 September 1958, and that flight call density was 10.265 calls per mile per night. Furthermore, the kill conditions of overcast and reduced visibility (4 miles or less in fog and/or drizzle) obtained in the area throughout the night. It is reasonable to assume, then, that some birds were being killed throughout the night.

On the night of 28–29 September 1959, migrants were first heard in the Champaign area at 0030, 29 September, and migration was heavy thereafter until dawn, the flight call density for the night being 14,940 calls per mile. The kill on this night probably occurred between 0030 and 0200 as this was the only time when both the migrants and the kill conditions were present. In this period the overcast lowered to 1,000 feet and visibility was reduced in fog. After 0200, the overcast broke and lifted, the visibility increased to 7 miles or better. From the above, we can place the time of the kill between 0030 and 0200 on 29 September.

In 1960, the kill occurred during the night of 19–20 September. The aural record for this night showed a flight call density of 12,043 per mile. Overcast prevailed from 2130, 19 September until the afternoon of 20 September, but the ceiling was 1,800 feet or more until 0055, 20 September, when it lowered to 1,200 and stayed throughout the night. Visibility was 7 miles until almost dawn of 20 September when visibility was reduced in haze and fog. The probable time of maximum kill was in this period of reduced visibility just at dawn on 20 September.

Because the time of kill is especially important in the ensuing discussion it is worth while to summarize the above data. In 1958, the kill of migrants occurred throughout the night, while in 1959 the peak kill probably occurred at about 0100, and in 1960, at 0500.

WEIGHT CHANGES RELATED TO FLIGHT

Nocturnal migrants probably take off shortly after sundown, and it is reasonable to assume that the samples of specimens from the different kills probably represent different periods of flight; i. e., in 1958, some birds were killed immediately after take-off, others flew most of the night before striking the tower; in 1959, birds were killed at 0100, having flown about seven hours

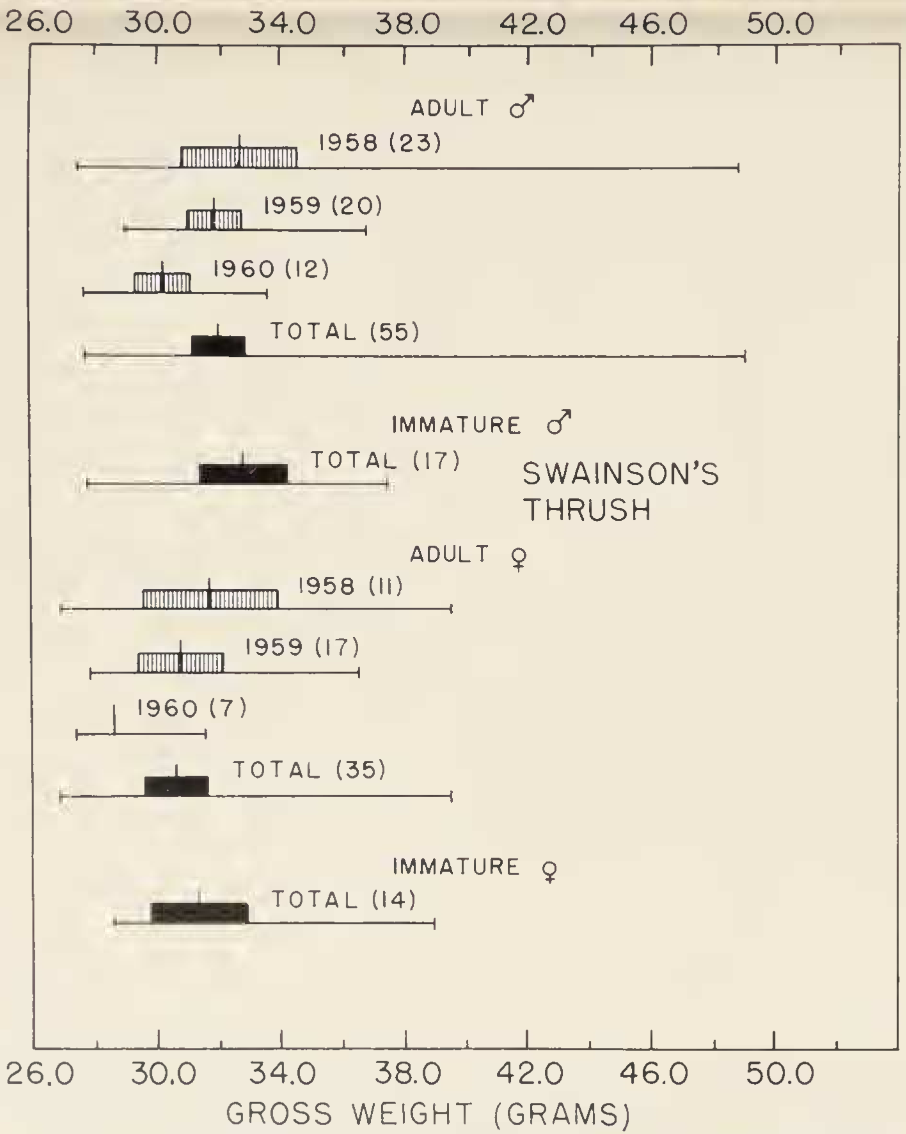

Fig. 1. Variation in gross weight of Swainson's Thrushes killed in nocturnal migration. Figure shows extreme variation and mean plus and minus two standard errors. Time of kills: throughout the night in 1958, 0100 in 1959, and 0500 in 1960.

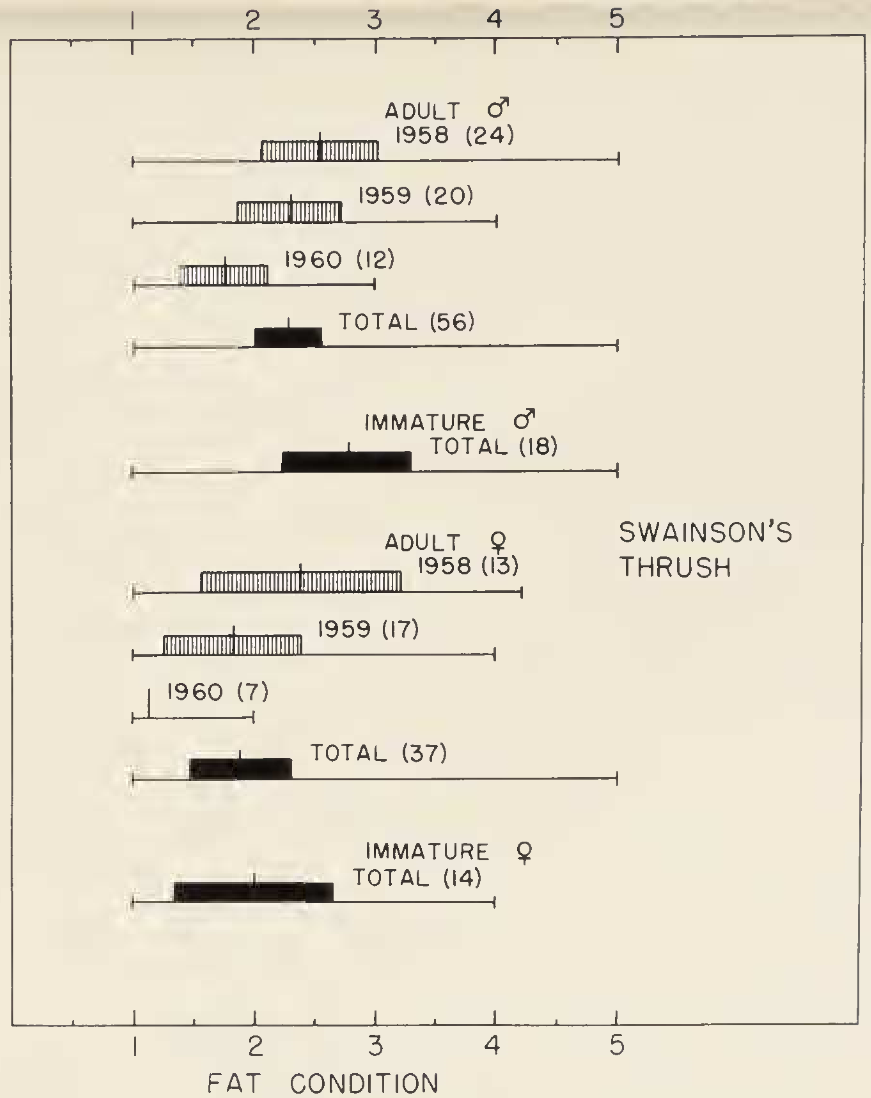

Fig. 2. Variation in fat condition of Swainson's Thrushes killed in noeturnal migration. Figure shows extreme variation and mean plus and minus two standard errors. Time of kills: throughout the night in 1958, 0100 in 1959, and 0500 in 1960.

(since sunset); and in 1960, birds were killed at about 0500, having flown about 11 hours.

More Swainson's Thrushes (126 specimens weighed) were killed than any other species. Gray-cheeked Thrushes were second (57 specimens weighed), and these species were used particularly in studying variability.

Variability in gross weight of Swainson's Thrushes is shown in Fig. 1 and Table 1. In this and other characteristics, variability was consistently higher in 1958 than in the two later kill samples. For instance, in 1958, the mean gross weight of adult male Swainson's Thrushes was 32.8 grams with a standard error of 0.94, while in 1959 the weight was 32.0 (SE = 0.47), and in 1960, 30.3 (SE = 0.46). Other sex and age classes and other organ weights show the same general pattern; i.e., high variability in 1958. There are several possible explanations for this differential in variability. Lacking information about the birds, except that relating to the kill, we can only speculate that the high variability in 1958 reflects the fact that birds from that sample were being killed during a ten-hour period, while the 1959 and 1960 samples represent only one- or two-hour kill periods.

This view is further supported by the fact that thrushes in the three samples become progressively lighter from 1958 to 1960. Migrants are presumably heaviest at the beginning of the night's flight and lightest at the end of it. The 1958 sample represents the entire night, or a mean time of midnight (6 hours of flight); the 1959 sample represents 0100 (7 hours of flight); and the 1960 sample, 0500 (11 hours of flight).

Salt and Zeuthen (1960) calculated a weight loss of 5.5 per cent of body weight per hour for a bird flying 31 mph. For the thrushes this would amount to about 1.8 g/hr or 18–20 g/night. The mean weights in our three samples do not indicate a loss of this magnitude.

The time difference between the kill of 1959 and 1960 was estimated to be four hours, and the mean weight difference in adult male Swainson's Thrushes between the 1959 and 1960 samples was only 1.7 grams or about 0.4 g/hr but both samples may include birds killed at other than the estimated time. Differences in weight between the heaviest adult male thrush in 1958 (presumably killed shortly after sundown) and the heaviest in 1960 (killed at 0500) was 15.4 grams or 1.4 g/hr. Comparable figures for the 1959 and 1960 samples indicate a gross weight loss of 0.8 g/hr.

These figures for gross weight loss are speculative, but weight losses by flying thrushes of 0.8–1.4 g/hr (2.6–4.4 per cent of gross per hour) are reasonable in view of the calculations by Salt and Zeuthen (1960). These authors discussed evaporative loss of water from birds during flight, and pointed out that this loss may amount to a considerable stress to birds in prolonged flight. Graber and Cochran (1960) showed that major night flights of migrants often coincide with overcast conditions. It is conceivable that conditions of overcast with high humidity or even light precipitation may be optimum for migration, because of the effect of such conditions in reducing dehydration. Further, this may be an additional point in favor of nocturnal (with cooler temperatures) versus diurnal migration for small birds.

From data on individual organ weights and fat deposition, we may determine what parts of the migrant are represented in the gross weight loss (Figs. 2–4).

Fat deposits in adult male Swainson's Thrushes decreased progressively in the samples from 1958 (fat index: 2.58) to 1959 (2.05) to 1960 (1.42). The difference in fat between 1959 and 1960 was significant ($t = 2.12$ with 2° of freedom). We cannot say how much weight this represents.

Connell, Odum, and Kale (1960) studied fat-free weights of birds and found this weight to be very constant. Mean fat-free weight of 10 specimens of female Swainson's Thrushes was 26.2 grams—4.6 grams lighter than our 1959 sample (fat factor = 1.8) and 2.4 grams lighter than our 1960 sample (fat factor = 1.1). The differences in weights and fat factors are not quite proportional, but the fat factor is only a rough estimate.

Actual weight data are available for principal organs. The mean weight of pectoral mass was comparable in 1958 (2.82 g) and 1959 (2.87 g) but significantly ($t = 4.41$ with 2° of freedom) lower (2.57 g) in the 1960 sample. The *entire* pectoral mass (both right and left breast muscles) accounts for about 0.60 grams, or about 30 per cent of the mean gross difference between 1959 and 1960. Other musculature might account for some of the difference in gross weight between the two samples. Even the difference in muscle weight in the 1959 and 1960 samples may actually represent fat rather than muscle tissue. George and Naik (1960) found fat content of breast muscle to be as high at 6.3 per cent in certain old world species of birds. This percentage would not account for the total breast weight difference in the two samples, but it is possible that migrants have an even higher fat content in muscle.

Surprisingly, liver weights were not significantly different in the different kill samples. In studying diurnal cycles of liver weights of Red-winged Blackbirds (*Agelaius phoeniceus*) and Starlings, (*Sturnus vulgaris*) Fisher and Bartlett (1957) found that the livers of roosting birds lost about 20 per cent of initial weight during the night. This difference in findings might reflect differences in the species studied, but more likely points out basic differences in the physiology of nutrient utilization between quiet roosting birds and birds in active flight.

None of the other organs weighed (heart, lung, and spleen) were significantly different in the three samples. Brain weights were taken only in 1960.

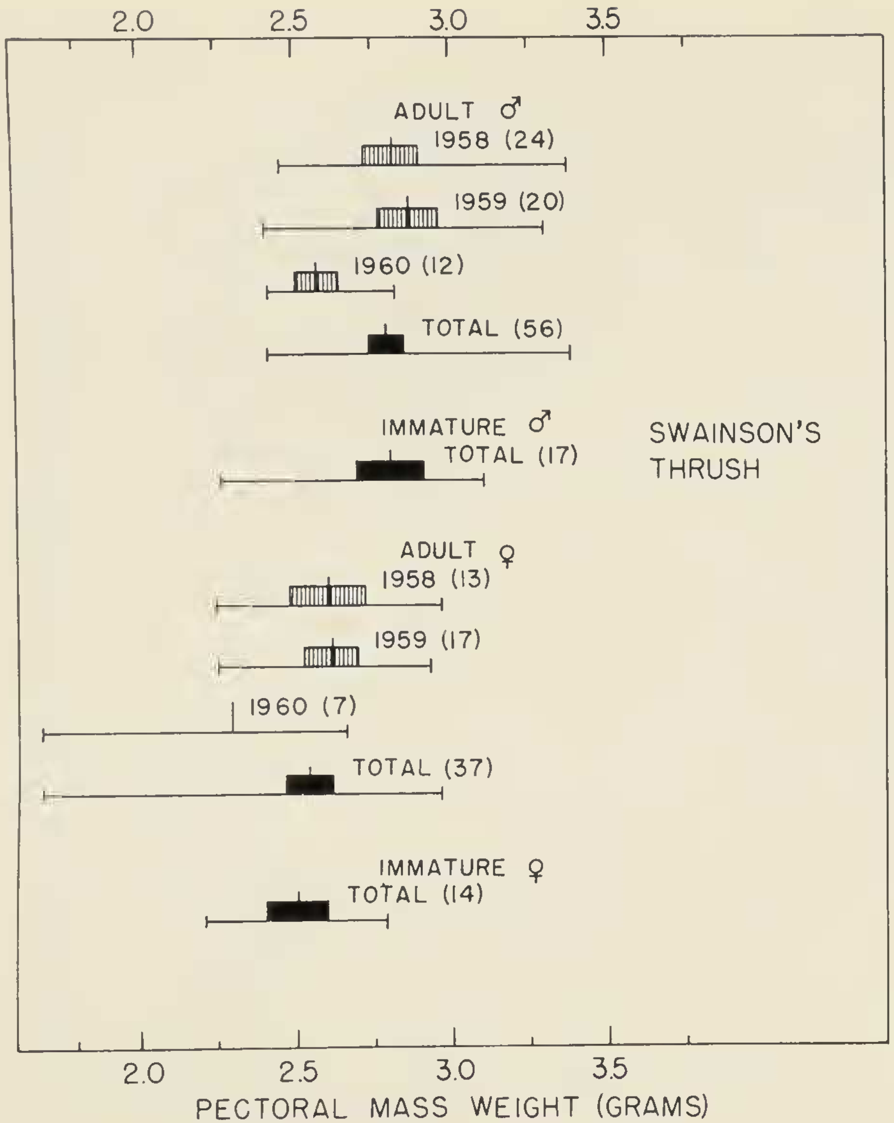

FIG. 3. Variation in pectoral mass weight of Swainson's Thrushes killed in nocturnal migration. Figure shows extreme variation and mean plus and minus two standard errors. Time of kills: throughout the night in 1958, 0100 in 1959, and 0500 in 1960.

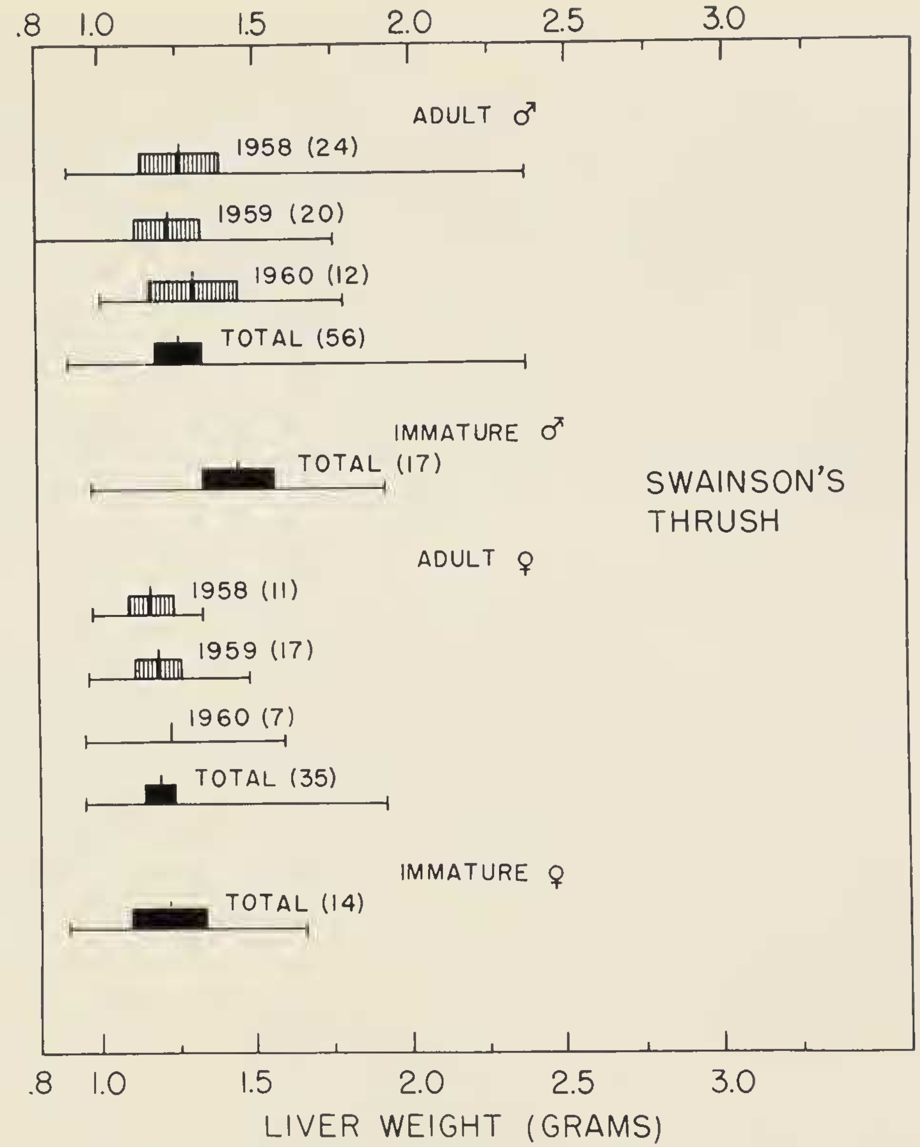

FIG. 4. Variation in liver weight of Swainson's Thrushes killed in nocturnal migration. Figure shows extreme variation and mean plus and minus two standard errors. Time of kills: throughout the night in 1958, 0100 in 1959, and 0500 in 1960.

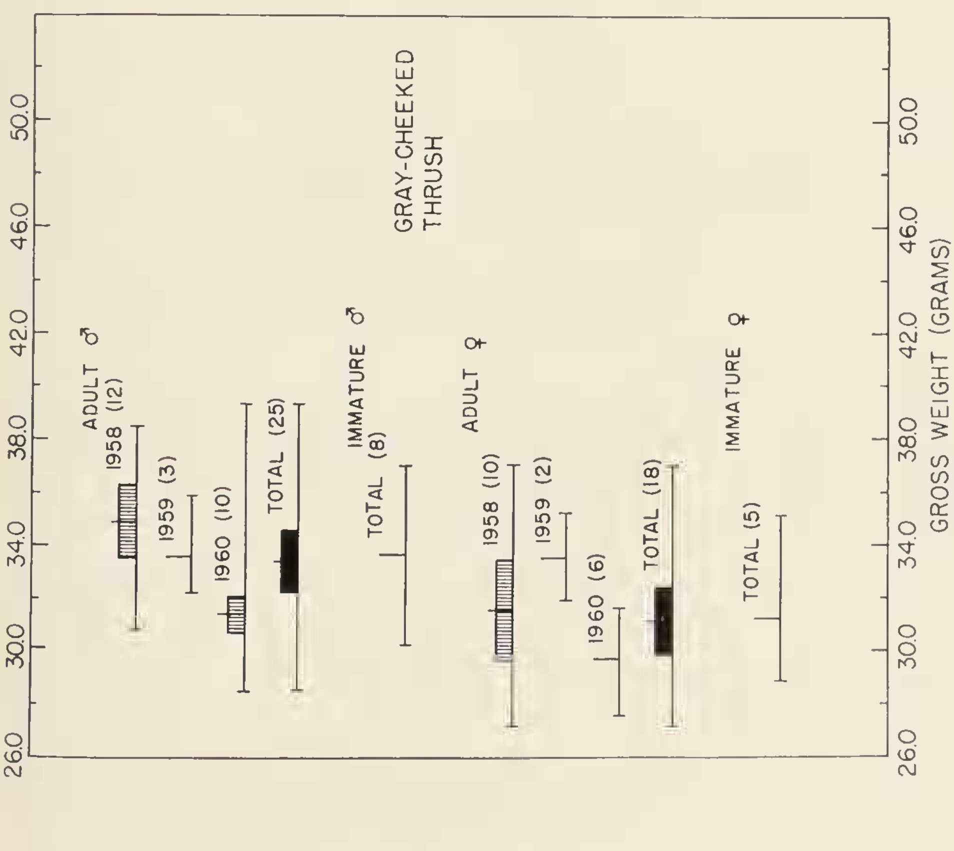

Fig. 5. Variation in gross weight of Gray-cheeked Thrushes killed in nocturnal migration. Figure shows extreme variation and means plus and minus two standard errors. Time of kills: throughout the night in 1958, 0100 in 1959, and 0500 in 1960.

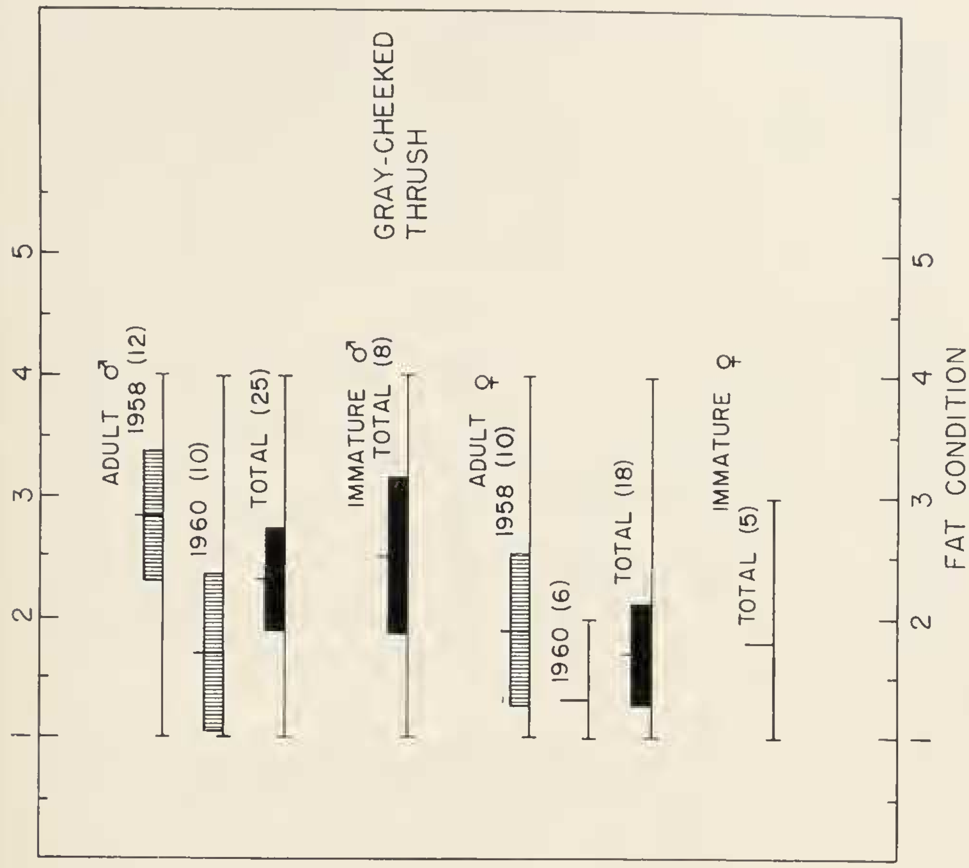

Fig. 6. Variation in fat condition of Gray-cheeked Thrushes killed in nocturnal migration. Figure shows extreme variation and mean plus and minus two standard errors. Time of kills: throughout the night in 1958, 0100 in 1959, and 0500 in 1960.

A large part of the gross weight loss discussed above might represent general dehydration. Of the factors considered, only pectoral muscle and fat contribute to the weight change. It was noted that pectoral muscles account for about 30 per cent of the weight loss. Water and fat apparently account for a large part of the remaining 70 per cent of gross loss.

WEIGHT VARIATIONS RELATED TO SEX, AGE, AND TAXONOMY

Data on variability in organ weights are presented in Figs. 1–8 and Table 1. Though detailed statistics are not available for most of the samples, some trends may be seen in the available data relating particular weight characteristics to certain species or families, and/or sex, and/or age.

Gross weight and fat condition.—In gross weight, males tended generally to be heavier than females, and immatures heavier than adults. The difference in age classes appeared to be related to fat condition, immatures usually being fatter than adults. In the Catbirds, and thrushes, adult males were also fatter than adult females.

There was marked variation in fat condition in different taxonomic groups. Bobolinks were in a class by themselves, all speimens being extremely fat (fat factor = 5). A small sample of immature female Palm Warblers had an average of 4.5, and male Catbirds 3.5. At the other extreme, Blackburnian (1 or less) and Black-and-white Warblers (1.5) were the least fat species.

Pectoral muscle weight.—In considering this and other organ weights, emphasis is placed on weight relative to gross weight, expressed as per cent of gross weight (Table 2). The importance of pectoral muscle weights in evaluating physiological condition in birds undergoing various stresses was first pointed out by Hanson (1958, 1961) in studies on Canada Geese (*Branta canadensis*). He also found heaviest pectoral muscle weights in adult male geese, a differential he has attributed to the nitrogen-conserving effect of the male sex hormone, androgen. In the species considered here it was generally true that males had relatively heavier pectoral muscles than females, and adults heavier than immatures.

Size (weight) of pectoral muscle does not always follow taxonomic lines in the species considered here. Relatively largest pectoral muscles were those of the Palm Warbler (9.0 per cent of gross in immature females), Veery (9.4 per cent of gross in adult males), Wood Thrush (9.6 per cent), and Ovenbird (9.1 per cent). Relatively smallest pectoral muscles were those of the short-billed Marsh Wren (5.4 per cent in immature females), a notably poor flyer: and the Yellowthroat (5.6 per cent in immature females), another poor flyer.

Of larger birds, the Bobolink (6.7 per cent in adult males) and Catbird (7.2 per cent) have light pectoral muscles in relation to gross weight. Actu-

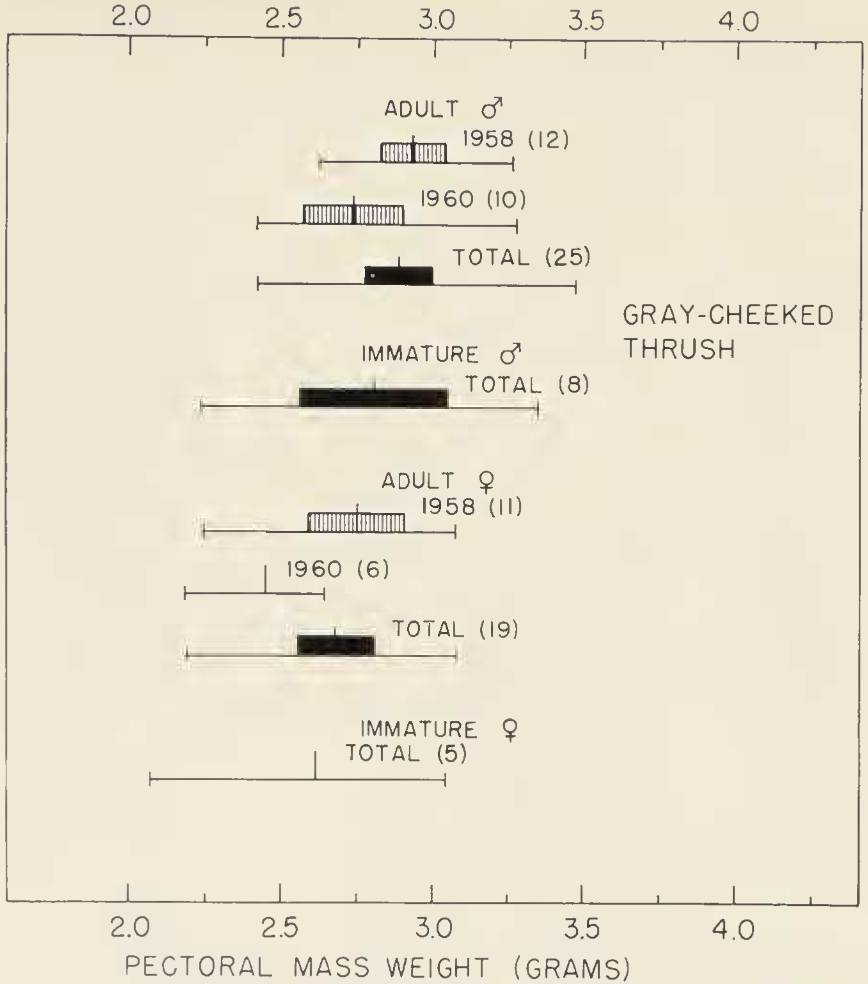

FIG. 7. Variation in pectoral mass weight of Gray-checked Thrushes killed in nocturnal migration. Figure shows extreme variation and mean plus and minus two standard errors. Time of kills: throughout the night in 1958, 0100 in 1959, and 0500 in 1960.

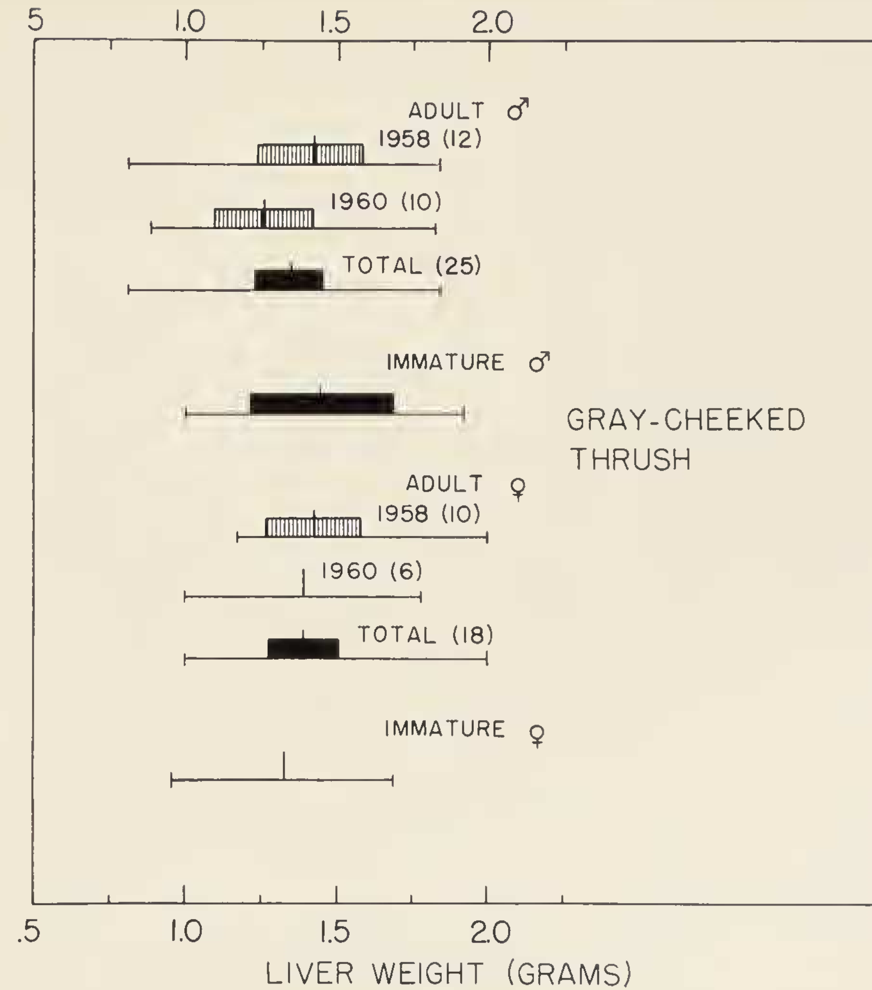

FIG. 8. Variation in liver weight of Gray-cheeked Thrushes killed in nocturnal migration. Figure shows extreme variation and mean plus and minus two standard errors. Time of kills: throughout the night in 1958, 0100 in 1959, and 0500 in 1960.

ally, in relation to body size, Bobolinks have reasonably large pectoral muscles, but the amount of fat carried by Bobolinks puts the gross weight and relative weight out of proportion to other species. Bobolinks appear to migrate both by night and day which poses the question: Do individuals of this species have less opportunity to replenish nutrient reservoirs than the more strictly nocturnal migrants? If they do, this undoubtedly bears on the remarkable fat deposition characteristic of this species.

In evaluating the relative weights of pectoral muscles and other organs in the species considered here, the reader is advised to bear in mind the fat condition factor. For instance, the Palm Warbler has a relatively heavy pectoral mass despite the fact that large fat deposits contribute to the gross weight and tend to reduce the relative value of the organ weight.

Brain weights.—One of the most surprising and, perhaps, potentially useful finds of this investigation was that relating brain weight to age.

Though our sample is admittedly limited, there is consistent indication that immatures have actually and relatively heavier brains than adults. Immature females usually had the heaviest brains of the four age-sex classes, with immature males next. In the thrushes, at least, adult females were also heavier-brained than adult males, so there is a sexual differential as well as a marked age difference.

Whether these weight differences are related to differences in water content or actual tissue structure, we cannot say.

It is conceivable that this information might prove useful in aging populations of birds in the same manner that Lord (1959) has utilized eye lenses to age mammals.

In the taxonomic groups, warblers and vireos appear to be relatively heavy-brained (3.0–5.5 per cent of gross weight) by comparsion with Bobolinks, grosbeaks, Catbirds, and thrushes (2.1–3.2 per cent). Again, fat condition, especially in the case of the Bobolink, tends to distort this percentage.

Heart weights.—Though statistical correlation is poor (correlation coefficient = 0.55, in the case of thrushes), heart weights tended to vary with body weight, showing no consistent variation with sex or age.

Relative heart weights varied from species to species, but the vireos tended to have large hearts (1.7–2.1 per cent of gross weight), the Catbird, thrushes, tanager, and grosbeak. smaller (1.2–1.6 per cent).

Lung weights.—Lung weights, like heart weights, tended to vary with body weight. No consistent variation with sex or age was apparent except in the vireos, among which females were consistently smaller lunged. than males. Largest (relatively) lungs occurred in the vireos, though lung weights were least variable in weights of the organs considered here.

Liver weights.—There was a marked tendency for immatures to have larger (heavier) livers than adults. Though less striking, there was also a sexual difference, males usually being larger than females. Probably in relation to this variation with sex and age there was a suggestion of an inverse relationship between pectoral muscle weight and liver weight. In the Catbird, for instance, adult males had mean pectoral and liver weights of 2.96 and 1.57 grams, respectively. For immature males those weights were 2.75 and 1.75 grams; for adult females: 2.70 and 1.52; for immature females: 2.64 and 1.69.

Relative liver weights were similar (3.5–4.0 per cent of gross) in most species, but those of the Gray-cheeked Thrush, *Dendroica* warblers, Tennessee Warblers and American Redstart tended to be heaviest, while those of the Bobolink, tanager, and grosbeak were on the low end of the scale.

SUMMARY

Gross weights and weights of organs (brain, peetoral mass, heart, lungs, and liver) were collected from 469 specimens (21 species) of nocturnal migrants killed in September 1958, 1959, and 1960 at a television tower near Champaign, Illinois. Migrants were killed throughout the night in 1958, around 0100 in 1959 (7 hours of flight), and 0500 in 1960 (11 hours of flight). For adult male Swanison's Thrushes (largest samples represented), gross weight loss was estimated at 2.6–4.4 per ccnt of gross per hour. Observable points of weight loss were fat deposition and pectoral mass (about 30 per cent of gross loss). A possible advantage of night (versus daytime) migration and migration under overcast (versus clcar) is thc reduction in water loss by migrants. Liver, heart, and lung weights did not appear to change in flight.

Gross weight and weights of certain organs appeared to vary with sex and age. Males tended generally to be heavier than females, and immatures heavier than adults. This relationship probably reflected fat condition as immatures were usually fatter than adults.

Peetoral muscle weight was higher in adults than in immaturcs and highest in adult males. Notably poor flycrs had relatively small pectoral muscles.

Brain weights, surprisingly, were greater in immatures than in adults, and greater in females than in males.

Heart and lung weights tended to vary with gross weight.

Liver weights were heavier in immatures than in adults, and tendcd to bc heavier in males than in females.

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